THE CURRENT STATUS OF ELECTRIC ARC FURNACE DUST RECYCLING IN NORTH AMERICA

Marc Liebman
AIM Market Research
3380 Babcock Boulevard
Pittsburgh, PA 15237, U.S.A.

ABSTRACT

We present the results of a telephone survey of electric arc furnace (EAF) steel producers. This report characterizes the current status of EAF dust generation, treatment and disposal. It indicates the quantity generated, zinc content, other relevant constituents, and plans and trends that will impact on the quantity and characteristics of the dust generated. The survey covers EAF based steel producers in the United States and Canada. It identifies the processors currently employed, opinions about the use of these processors and services, as well as new technologies being considered.
INTRODUCTION

The objective of this study was to make an up-to-date assessment of the generation and disposal of electric arc furnace (EAF) dust in the U.S. and Canada. This report provides a detailed summary of the results of this research.

In the 1980s, the U.S. EPA promulgated regulations which listed emission control dust from the primary production of steel in an electric arc furnace, identified as KO61, as a hazardous waste. Throughout the 1990s, regulations evolved which required that this dust be either treated in a High Temperature Metals Recovery (HTMR) process or stabilized chemically to allow it to be disposed of in a landfill. (Similar regulations were also established in Canada.) HTMR processing and landfilling now account for most of the disposition of EAF dust generated in the U.S. and Canada. This study endeavors to quantify and characterize the EAF dust generated in the U.S. and Canada and the current disposition of this material.

The basis of this study was a telephone survey of 76 electric arc furnace (EAF) shops in the U.S. and Canada. This survey was conducted from March 17 to April 28, 2000. One hundred twenty-seven interviews were completed with appropriate and knowledgeable personnel in the EAF shops surveyed.

The results of the study were also analyzed by examining five segments. These segments were Minimill Carbon Strip Steel producers, Other Flat Roll Carbon Steel producers, Long Products Minimills, Specialty Long Products mills, and Stainless Steel producers. Presentation of the analysis of results by segment is limited in this manuscript in order to comply with the guidelines specified by TMS.

GENERAL EAF MELT SHOP INFORMATION

EAF steel production in the U.S. and Canada continues to capture an increasing share of the total steel production. All new steel plants commissioned since 1992 have been based solely on EAF steel production, therefore basic oxygen furnace (BOF) steel production as a share of the total production in the U.S. and Canada is declining. Even BOF based steel producers are replacing BOF steel production with EAFs. This trend is the most significant factor in the overall increase in the generation of EAF dust.

EAF shops in the survey produced 54.7 million tons of steel in 1999, and are operating at roughly 82% of their capacity of 67.1 million tons. This surveyed sample represents 94% of the total EAF steel production in the U.S. and Canada and approximately 44% of the total steel production (123.8 million tons) for the U.S. and Canada in 1999. Overall, the EAF shops that responded to the survey projected an 11% increase in annual steel production in 2000.

Carbon steel production accounted for 81% of the steel produced by the EAF shops surveyed, alloy steels accounted for 15%, stainless steel accounted for 3%, and resulfurized and silicon steels accounted for the remaining 1%.

IRON BEARING CHARGE MATERIAL MELTED
The types of scrap and other iron bearing charge materials (IBCMs) consumed in the production of steel have a significant impact on the quantity of EAF dust generated. Higher qualities of steel scrap contain less residuals and other heavy metals, such as zinc, lead, cadmium, etc. and lesser qualities of steel scrap result in greater dust volumes and higher levels of these heavy metals in the dust.

Types of IBCM Melted

*Shredded* scrap is the type of iron bearing charge material most frequently (85%) melted by the EAF plants surveyed. At least 50% of the plants also use *Home Revert, No. 2 Heavy Melt* and *No. 1 Heavy Melt*. A total of 13 different IBCM qualities were identified by at least 25% of the EAF shops surveyed.

Share of Total IBCM Consumed

*Shredded* scrap also accounts for the largest single share (25%) of iron bearing charge material consumed by the EAF shops that responded. In all, five types of material account for 62% of the total iron bearing charge materials consumed by the plants surveyed. After *Shredded, No. 1 Bundles* makes up the next largest share (16%). Three different other types of material each account for a 7% share of consumption (*Bushelings, Pig Iron, DRI/HBI/Iron Carbide*).

Changes Expected in IBCM Consumption

Overall, 25% (18) of the EAF shops that responded foresee changes in the types of iron bearing charge material that will be melted in the future. Overall, 81% (13) of the 18 EAF shops surveyed that foresee changes in the types of iron bearing charge material believe they will be due to changes in *Scrap Availability* and changes in the *Prices* of these materials. Of these 18 EAF shops, 63% (10) foresee changes in the types of *Grades Melted*.

EAF DUST GENERATION AND COMPOSITION

Quantity of EAF Dust Generated

A total of 1,069,457 tons of EAF dust was generated by the plants surveyed in 1999. All the EAF shops in the U.S. and Canada are estimated to have generated a total of 1.2 million tons of EAF dust in 1999. Thus, the survey accounted for approximately 90% of EAF dust production during that year. The 40 *Minimill Long Products* facilities that generated EAF dust accounted for 49% of the EAF dust generated by the plants surveyed. However, the nine EAF *Minimill Carbon Strip* plants surveyed alone accounted for a 27% share of the total EAF dust generated.

Rate of EAF Dust Generation

Overall, 82% of the EAF shops that responded to the survey generated from 25 to 44 pounds of EAF dust per ton of steel produced. Figure 1 provides a distribution of the generation of EAF dust per ton of steel produced.
The EAF *Minimill Carbon Strip* plants generated the most EAF dust per ton of steel produced. Of the EAF *Minimill Carbon Strip* plants surveyed, 77% generate at least 35 pounds per ton of steel produced.

Overall, 42% (31) of the EAF shops that responded each generate within the range of 7,500 to 14,999 tons of EAF dust per year. On-site EAF dust treatment will only be considered where the economies of scale necessary to justify the capital expense of an on-site treatment technology are realized. The survey reveals the rarity of instances in which an adequate level of EAF dust is generated to justify an on-site facility employing currently commercially viable technologies. Only seven of the EAF shops surveyed generated 30,000 tons or more of EAF dust per year, five of which were in the *Minimill Carbon Strip* segment. Of *Minimill Carbon Strip* EAF shops surveyed, 56% (5 of 9) each generated 30,000 or more tons of EAF dust annually. The other two EAF shops which generated 30,000 tons or more EAF dust per year produce carbon steel long products. Plants with this level of EAF dust generation provide the strongest opportunity for justifying on-site EAF dust treatment. The *Minimill Long Products* and *Specialty Long Products* plants exhibited a similar distribution profile regarding EAF dust annual generation. Figure 2 provides a distribution of the generation of EAF dust generated per year.
Of the EAF shops that responded, 88% (63 of 72) indicated that they do not expect any change in the quantity of EAF dust generated. Furthermore, of the nine plants that did project a change, all but one expected the volume of EAF dust to decline. Of these eight shops that projected a reduction, five believed that the reduction would be attributed to an effort to minimize the quantity of EAF dust generated, or to a change intended to achieve that objective.

**Typical Chemistry of EAF Dust Currently Generated**

The chemistry of EAF dust is a significant factor in determining the potential viability of recycling to recover metals. In carbon based steel production, zinc oxide recovery provides the best opportunity to obtain some value by recycling EAF dust. A limited number of zinc producers use crude zinc oxide from an HTMR facility to produce zinc.

Overall, 47% (29) of the 62 EAF shops that responded indicated that the percentage of zinc oxide (ZnO) in their EAF dust ranges from 15 to 24.9% and 21% (13) have a zinc oxide content of 25% or more. Figure 3 indicates the share of EAF shops that responded overall that generate EAF dust within a range of zinc oxide content.

![Figure 3 - Percent Zinc Oxide Content in EAF Dust Generated by (62) Plants Surveyed](image)

Overall, 40% (25) of the 61 EAF shops that responded indicated that the percentage of lead oxide (PbO) in their EAF dust is less than 1%. Another 31% have 1 - 1.99% lead oxide in their EAF dust. While recovering zinc oxide has potential economic benefit, the lead oxide content can diminish the value of recycling. Although some processes may ultimately result in the recovering of lead metal, in an HTMR process, the lead oxides are volatilized with the zinc oxides and contaminate the crude zinc oxide that is recovered. Consequently, lead oxide content has a negative impact on the value of EAF dust. Figure 4 indicates the share of EAF shops overall that generate EAF dust within a range of lead oxide content.
Overall, 47% (29) of the 61 EAF shops that responded indicated that the percentage of cadmium oxide (CdO) in their EAF dust is 0.04% or more. The problem with cadmium oxide is similar to that with lead oxide. Cadmium oxides are captured with the zinc oxide and also have a negative impact on the value of the zinc oxides. Figure 5 indicates the share of EAF shops overall that generate EAF dust within a range of cadmium oxide content.

Overall, 47% (30) of the 64 EAF shops that responded indicated that the percentage of iron oxide (FeO) in their EAF dust is 30% or more. The iron oxide content in EAF dust can be viewed as both positive and negative. Of course, zinc has a higher potential value compared to iron, so to the extent that iron displaces zinc, it diminishes the recycling value of the dust. However, recovery of the iron may be considered a positive economic factor, particularly when the recycling process employed involves recharging or injecting EAF dust back into the EAF melting process. Figure 6 indicates the share of EAF shops overall that generate EAF dust within a range of iron oxide content.
Overall, 34% (16) of the 47 EAF shops that responded indicated that the percentage of lime (CaO) in their EAF dust is 10% or more. Figure 7 indicates the share of EAF shops overall that generate EAF dust within a range of lime content.

Charging Lime into the EAF

Steel producers add lime (CaO) to desulfurize the steel in the EAF. The practice employed in charging lime to the EAF can have a significant impact on the volume of the EAF dust generated. For example, when lime is injected pneumatically through the roof of an EAF, the lime can end up being sucked out the fourth hole along with the furnace off-gases.

Overall, 63% (38) of the 60 EAF shops that responded revealed that lime is charged into the EAF by first charging it into a Scrap Bucket. The next most common lime charging method is Injection (23%). This includes Injection in the front or side of the furnace, through the roof, or through a “fifth hole”. When using a Scrap Bucket to charge lime, the lime content in the
dust declines. When charging lime directly either into the furnace or through the roof, the lime content in dust tends to increase. Only 44% of the plants with a lime content above 15% use a scrap bucket. In contrast, the plants that have less than 15% lime in their dust predominantly are using a scrap bucket in 70 to 80% of the cases. This is illustrated in Figure 8.

![Figure 8 - Correlation Analysis Between % CaO in EAF Dust and Method of Charging Lime (CaO)](image)

One EAF based steel plant realized a “dramatic reduction” in the lime content of its EAF dust by no longer charging lime through the roof, instead using a scrap bucket. Another EAF shop discontinued injection because they had a high lime content in the EAF dust. When the lime was pneumatically injected, the CaO content in the dust was 60 - 70% higher than the present level; they now charge lime via a scrap bucket. One other EAF steel producer reduced its EAF dust volume by charging pebble lime to the EAF in a scrap bucket.

**CURRENT EAF DUST DISPOSITION**

The two fundamental options for disposing of EAF dust are landfilling and recycling. Several factors are essential to the decision of selecting either alternative. The main factors are economic (treatment and transportation costs), environmental (regulations and conservation), long term liability, and concerns over public opinion. Overall, 63% (47) of the 75 plants that responded arrange to have EAF dust recycled in a High Temperature Metals Recovery (HTMR) facility, 41% (31) utilize a Landfill, and 5% employ other recycling techniques. Several employ more than one disposal solution. This is illustrated in Figure 9.
Overall, 54% (586,939 tons) of the total quantity of EAF dust generated by the plants surveyed is recycled; 45% (470,518 tons) is landfilled. While some plants employ both options, the majority of the plants employ either one method or the other exclusively.

**Landfilling of EAF Dust**

Of the plants that landfill their EAF dust, 77% (24 of 31) landfill 100% of this dust. Another 10% (3) landfill at least 60%. In 93% (28) of the cases, the EAF dust is chemically treated prior to landfill.

Of the plants that use a landfill, 87% (27) use a facility that is off-site. The remaining four plants use an on-site landfill facility which is owned by their company. Of the 27 plants that dispose of EAF dust in an off-site landfill, 59% (16) use Envirosafe. Envirosafe of Ohio alone accounts for a 41% (11) share of firms using off-site landfilling. Safety Kleen accounts for a 26% (7) share of these plants.

Only seven plants commented on the remaining life of their off-site landfill. Two indicated a remaining life of less than 10 years, two expected a remaining life of approximately 10 years, and three had a remaining life of more than 10 years. Twenty-five plants reported the locations of the landfills that they use. Overall, 28% (7) ship their EAF dust at least 500 miles for landfill disposal. Slightly fewer than half of these plants only need to ship their EAF dust less than 200 miles.

**Recycling of EAF Dust**

Overall, 86% (44) of the 51 plants that recycle their EAF dust recycle 100% of their EAF dust, and another 8% recycle at least 50%. Six of the EAF shops surveyed recycle all or a portion of their EAF dust in an on-site facility or directly into their EAF. Three other plants acknowledged having had on-site EAF dust processing operations in the past. Two plants acknowledged that they are considering a new on-site EAF dust treatment technology.

Each plant that is not considering an on-site EAF dust treatment facility was asked what would motivate them to consider a new on-site technology. Overall, 46% (32) of the plants that responded said they would consider it if it were more *Cost Effective* than the present practice. However, 33% (23) of the plants said that they would not consider it in any case, believing that
economies of scale would not permit an on-site facility to be economically viable considering today’s known EAF dust processing technology.

Overall, 67% (31) of the 46 plants that recycle their EAF dust through an off-site processor use one or more of the Horsehead facilities. Horsehead of Palmetto, PA alone accounts for a 33% (15) share of the plants surveyed that use an off-site recycling facility. Another 33% (15) use Zinc Nacionale. Overall, 38% (17) of the 45 plants that identified the location of their off-site EAF dust recycling facility ship their EAF dust at least 500 miles for processing. Only 31% (14) of these plants only need to ship their EAF dust for landfill less than 200 miles.

**DRIVERS AND TRENDS FOR EAF DUST PROCESSING**

Each plant was asked to indicate the relative importance of four leading drivers for EAF dust processing. Overall, Economic Issues was the most frequently identified driver in the survey regarding EAF dust processing. Regulatory Considerations and Industry Dynamics (such as Scrap Types) were of secondary importance. Technological Factors was the least frequently identified driver. However, all four drivers must be considered important in seeking solutions to the EAF dust steel industry environmental dilemma. When asked to rate the level of their present activity in dealing with these four drivers, the facilities’ responses were distributed as indicated below in Table I:

<table>
<thead>
<tr>
<th>Drivers</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Issues</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Regulatory Concerns</td>
<td>62%</td>
<td>37%</td>
<td>1%</td>
</tr>
<tr>
<td>Industry Dynamics/Scrap Issues</td>
<td>45%</td>
<td>54%</td>
<td>1%</td>
</tr>
<tr>
<td>Technological Factors</td>
<td>3%</td>
<td>71%</td>
<td>26%</td>
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**Economic Issues**

When asked to rate the importance of reducing the cost of processing EAF dust, all but two plants replied “10” (on a scale from 0 to 10, 10 being highest). The highest level of activity among EAF steel producers in responding to EAF dust treatment and disposal drivers involves Economic Issues. When asked to describe their plant’s level of activity regarding Economic Issues associated with EAF dust, all plants indicated “High”.

Overall, 95% (72) of the plants surveyed acknowledged paying a processor to handle their EAF dust. However, only 11 plants would reveal the fee or fee range. The processing fees indicated by these plants ranged from a low of $70 per ton to a high of $150 per ton. The cost of recycling is generally higher than the cost of landfilling, except where either is affected by transportation costs. Figure 10 provides a distribution of the total cost of processing (including transportation) indicated by individual plants surveyed, whether the EAF dust is recycled (R) or landfilled (L), and the distance shipped.
Of the 72 plants that pay a processor to handle their EAF dust, 10% (7) expect the processing fee to increase, while 53% (38) do not. The remaining plants replied that they did not know what to expect. Of the seven that expect the fee to increase, five acknowledged that they expect this trend to continue. Of the 38 EAF shops overall that do not expect the EAF processing fee to increase, 53% (20) expect the stabilization of the EAF dust processing fee to remain this way.

**Regulatory Considerations**

Based on the responses, it is clear that EAF steel plants are actively involved in addressing the *Regulatory Considerations* associated with EAF dust processing. Overall, 62% of the EAF plants surveyed indicated a “High” level of activity in dealing with *Regulatory Considerations* and another 37% indicated at least a “Medium” level of activity.

Generally speaking, the plants surveyed expect the regulations for treatment and disposal of EAF dust shall reflect the status quo. The regulatory authorities are keeping a low profile, insuring compliance and enforcement of the existing regulations. Processors and acceptable treatment technologies have been in place for some time and appear to be handling EAF dust to the satisfaction of the regulatory agencies. *State* regulations are typically of the greatest concern to the EAF plants overall. In many cases the United States EPA has delegated enforcement to the state authorities.

**Industry Dynamics/Scrap Issues**

Overall, 45% of the EAF plants surveyed indicated a “High” level of activity in dealing with *Industry Dynamics/Scrap Issues* such as availability of types of scrap, and another 54% indicated at least a “Medium” level of activity.

**Technological Factors**

Overall, 71% of the EAF plants surveyed indicated a “Medium” level of activity in dealing with *Technological Factors* and another 26% indicated a “Low” level of activity.
Each of the plants surveyed was asked to identify emerging EAF dust treatment technologies. Ezinex was the most frequently identified, followed by Frit (Fertilizer) and Elkem. Other technologies mentioned by only one or two plants were: Hydro metallurgical plus thermal, Allmet, Inmetco, American Metals Recovery, Plasma, RMT Phosphate Additions, Heritage and Waste Management.

All EAF shops indicated a “9” or “10” level of interest in response to the question of whether they would be interested in minimizing the amount of EAF dust generated. All of the EAF shops were aware of using a non-foamy slag as a method of EAF dust reduction, but none was using it. Overall, 64%(48) of the EAF shops surveyed were using a non-pneumatic lime feeding method, while another 30% (27) were merely aware of it. Though no EAF shops surveyed were using adjustable speed drive baghouse fans as a method of EAF dust reduction, all were aware of this possibility. Also, while all facilities were aware of using scrap preheating as a method of EAF dust reduction, only five were using it.

**Leading Trends in EAF Dust Processing**

The leading trend in EAF dust processing is an ongoing and concerted effort by steel producers to Reduce Spending, followed by a significant effort to Reduce EAF Dust Volumes. Overall, 68% of the plants commented that Reduced Spending on EAF dust processing is their main focus and 45% mentioned Reduced Dust Volume. Overall, 81% (51) of the 63 plants that responded expect that these trends will impact upon the viability of their operation.

**VENDORS AND VENDOR ISSUES**

Each EAF shop was asked to identify the three leading processors of EAF dust technology and equipment. Overall, Horsehead was identified by 98% (61) of the 62 plants that responded, followed by Envirosafe with 74% (46), and Zinc Nacional with 63% (39) recognition.

Overall, Horsehead handles 36% of the EAF dust generated by the plants surveyed, followed by Envirosafe with a 23% share, and Zinc Nacional with a 15% share. Of the total landfilled EAF dust by the shops surveyed, Envirosafe takes care of 53%, followed by Safety Kleen with a 15% share. Of all recycled EAF dust, Horsehead takes care of 65% followed by Zinc Nacional with a 27% share, and the balance is left to others.

Only five EAF shops said they plan to change their EAF dust processor. Just four acknowledged seeking a new solution for EAF dust disposition.

**SUMMARY**

In summary, despite continuing efforts to reduce the volume of electric arc furnace dust generated, the total volume of EAF dust generated by steel producers continues to grow. EAF dust disposal and treatment is a cost of EAF steel production that contributes nothing to the value of the steel produced. It is a cost burden that continues to plague EAF steel producers. A limited number of options for disposal and recycling are presently employed. EAF steel
producers are ripe for considering any new technologies or treatment alternatives that will reduce the volume of EAF dust generated and ultimately the cost of processing EAF dust.

REFERENCES


